

Evaluation of the Use of Electricity for Predator Removal at the Tracy Fish Collection Facility

Investigators

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Summary

Federal and state fish screening facilities in the south Sacramento-San Joaquin Delta have been known to provide favorable habitat for predator fish, primarily striped bass *Morone saxatilis* (Gingras 1997, Bark *et al.* in draft). Predators tend to concentrate in and around fish screening facilities in zones where water velocities are lower (Bark *et al.* in draft). At the Tracy Fish Collection Facility (TFCF), striped bass are frequently found residing upstream, downstream, and within the facility (Bark *et al.* in draft). Striped bass are piscivorous fish that consume smaller fish and can reside within the TFCF year round feeding on seasonal influxes of entrained fish. Thus, striped bass can sustain a viable population within and near the facility as long as they have favorable environmental and feeding conditions (Bark *et al.* in draft). According to the Reasonable and Prudent Alternative in the 2009 National Marine Fisheries Service Biological Opinion, by December 31, 2011, Reclamation shall complete studies to determine methods for removal of predators in the primary channel, using physical and non-physical removal methods (*e.g.*, electricity, sound, light, CO₂), with the goal of reducing predation loss to 10% or less.

At the TFCF, louvers in the primary channel guide fish to one of four 6-inch-wide primary bypasses. The bypasses transition into pipes which carry the fish and flow into a secondary channel. A secondary set of louvers guide fish through another fish bypass and into the holding tank area. Predator fish removal in the secondary channel is conducted periodically by lowering the secondary channel water level and manually removing predators. High flows are released through the fish bypasses to force predators out of the bypass pipes where they can be netted and removed. Predator removal is more difficult in the primary channel due to the larger channel width, larger water depth, and the inability to dewater the channel. Gill nets and hook-and-line are the current options for predator removal in the primary channel.

The goal of this study is to investigate the potential for using electricity as a safe and effective way of deterring or preventing large predator fish from taking up residency in the primary channel of the TFCF. The target size class for predator removal is fish larger than 400 mm. Large fish are more susceptible to the electrical field than smaller fish; however, the effects of the field on an individual can depend on the specific location of the fish in the field. Maintaining field intensity low enough to avoid tetany in larger fish should allow smaller fish to pass through the field unharmed. Of particular interest is the need to minimize effects on steelhead in the range of 200–250 mm. Real-time monitoring will be needed to determine if species of interest are present so that electrical crowding does not occur.

Electric fish barriers are typically produced by submerging two or more metal electrodes in a fixed location and applying a voltage between them. An electrical current passes between the electrodes, forming an electrical field in the water. Fish in contact with the electrical field can experience a reaction from slight twitch to full paralysis. Response levels of twitch (slight muscle contraction or swimming avoidance), taxis (forced swimming to anode), or tetanus (full paralysis/immobilization) depend on the peak voltage, peak current, pulse width, frequency, and duration of the applied electrical field. Electric fish barriers are commercially available. In certain circumstances, electric barriers have been shown to be effective as a behavioral tool in controlling fish movement during upstream passage or movement into flow (Clarkson 2004). However, only limited testing has been conducted to document the effectiveness of electric fields as a behavioral barrier during downstream movement of fish (Sechrist *et al.* in draft).

Past Research

In FY 2010, a small-scale laboratory tank was used to measure the amount of power required to produce various response levels for a predator species at the TFCF, striped bass, in the size range of 254–368 mm (mean 315 mm) total length (TL). The water conductivity was maintained at 0.4 mS/cm (7-year average water conductivity at the TFCF) based on data from *Water Quality Data Downloads from the Tracy Fish Collection Facility (TFCF)*, http://www.usbr.gov/pmts/tech_services/tracy_research/data/WaterQualityData.html.

Flat-plate electrodes were affixed to the ends of the tank and a uniform voltage gradient was applied through the tank using a Smith-Root generator-powered pulsator unit GPP 9.0. The waveform of the pulsed direct current (DC) signal was observed with an oscilloscope and the voltage gradient was measured with a gradient meter. Response levels from twitch to taxis to tetanus were observed and documented for 26 fish during the experiments. Results are shown in Table 1. Power transfer theory can be used to correlate the amount of power required to elicit a specific response at certain water conductivity to any other water conductivity (Kolz and Reynolds 1989).

Table 1.—Physiological response of striped bass in the size range of 250–370 mm TL to pulsed DC at a frequency of 7.5 Hz and pulse width in the range of 1.25–2.9 ms.

Striped Bass Response	Voltage Gradient (V/cm)
No response	< 0.05
Twitch	0.05–0.3
Moderate taxis	0.3–0.75
Strong taxis	0.75–1.5
Tetanus	1.5–3.1

An analysis of potential installation locations for electricity at the TFCF was completed. Potential applications of the use of electricity include:

- Fixed rolling electric crowder throughout the primary channel to move predators into bypasses for collection in the secondary channel
- Fixed localized electrode installation in a specific location (*e.g.*, along the right primary channel sidewall or downstream of the trashrack piers) to move predators away from preferred low velocity regions
- Fixed electric barrier upstream of trashrack to minimize entrance of predators into facility
- Automated harvesting techniques to net or cage fish through taxis response
- Manned boat electrofishing to net fish through taxis response
- Electric barriers on end of bypass pipes to prevent predators from swimming upstream during secondary channel predator removals

Several options were eliminated due to personnel or public safety concerns or logistical constraints. Limiting the amount of power applied to the water was deemed important in order to minimize impact on smaller fish. After reviewing options, more research was warranted to determine if a fixed rolling electrical field can be effective at moving predators downstream.

Problem Statement

The objective of this study is to determine whether the use of electricity as a predator removal technique is viable at the TFCF. In FY11, a rolling DC electrical crowder was designed and installed in an acrylic flume at Reclamation's Hydraulics Laboratory in Denver, Colorado. Electrical properties such as peak voltage, pulse width, and frequency determined during the stationary tank tests will be applied to the electrical crowder system. The magnitude and extent of the electrical field will be measured with a voltage gradient meter. Researchers will observe and record the response of large

predators and smaller-bodied fish to a rolling electrical crowder in moving water at 0.46 and 0.76 m/s (1.5 and 2.5 ft/s). If predators are successfully crowded downstream without adversely affecting smaller-bodied fish, a screen and bypass system will be added to the model to determine if striped bass will enter a 15.2-cm-wide (6-in-wide) bypass when a rolling electric field is produced.

Goals and Hypotheses

Goals

1. Determine whether a rolling DC electrical crowder can move striped bass downstream through avoidance or forced swimming without causing immobilization. Determine 72-h survival of the exposed fish.
2. Record whether smaller-bodied fish show any noticeable response (twitch, taxis, tetanus) to a rolling DC electrical crowder of sufficient power to move striped bass downstream. Determine 72-h survival of the exposed fish.
3. Determine if velocity affects the response of striped bass to the electrical crowder at 0.46 and 0.76 m/s (1.5 and 2.5 ft/s).
4. Determine if striped bass chose to enter a 15.2-cm-wide (6-in-wide) bypass when a rolling electrical field is produced or if impingement occurs on the angled screen.

Null Hypotheses

1. Striped bass will not move downstream when exposed to a rolling DC electrical field.
2. Small-bodied fish will not show any response (twitch, taxis, tetanus) to the rolling DC electrical field.
3. Channel velocity will not affect fish response.
4. Striped bass will not enter a 15.2-cm-wide (6-in-wide) bypass when a rolling electrical field is produced.

Materials and Methods

An acrylic flume in Reclamation's Hydraulics Laboratory in Denver, Colorado is being used to test the rolling DC electrical crowder concept. The flume is 0.76 m wide \times 0.91 m high \times 4.88 m long (30 in wide \times 36 in high \times 16 ft long) and contains a headbox with curved transition walls and a fish collection system in the tailbox. Water can be chilled and re-circulated in a system separate from the laboratory water system if water temperature or quality is not acceptable. Black plastic is draped over the flume to limit disturbance by human interaction. A video camera system with four remote cameras and a DVR digital recording device is installed underneath of the cover to observe and document fish behavior during the tests.

To test the electrical crowder concept, electrodes (10 gage copper wire) are attached to the inside of the flume walls at 0.46 cm (18 in) spacing. A Smith-Root Model LR-24 Electrofisher unit transmits pulsed DC to an electrical sequencer designed and built by an electrical engineer at the Technical Service Center (www.smith-root.com). The sequencer pulses DC to successive electrode pairs. The operator can adjust whether the anode or cathode is the upstream electrode in the pair and how quickly the electrical field rolls down the flume. Ideally, the electrical field should move at a velocity slower than the velocity of the water so that any stunned fish will drift out of the electric field. Electrical properties such as peak voltage, pulse width, and frequency can be controlled independently by the electrofisher unit. A voltage gradient meter is used to measure the magnitude and extent of the electrical field produced by an electrode pair.

Temperature and water conductivity is measured before each experiment. Since water conductivity in the laboratory water system is approximately 0.30 mS/cm, power transfer theory can be used to correlate the amount of power required to elicit a specific response at 0.4 mS/cm from the previous experiments to a water conductivity of 0.30 mS/cm (Kolz and Reynolds 1989). Target water velocities of 0.46 and 0.76 m/s (1.5 and 2.5 ft/s) are measured with an acoustic Doppler SonTek FlowTracker. The target water depth of 50.8 cm (20 in) is measured with a staff gauge.

Striped bass in the size range of 285–540 mm (11–21 in) TL are currently available in Reclamation's aquaculture facility. This size range allows researchers to observe a range of responses for large bodied predators. Juvenile salmon sized at about 100 mm (4 in) TL are also available in the aquaculture facility. The juvenile salmon will be used as the small-bodied test fish. If the electrical crowder concept advances to a field application, rainbow trout in the range of 200–250 mm (8–9 in) may need to be tested in the laboratory flume to observe the potential response of steelhead.

Sets of control tests will be run before the treatment is applied. Control fish will be tested one at a time at 0.46 and 0.76 m/s (1.5 and 2.5 ft/s) under the same transport, handling, testing, and collection procedures as fish experiencing the treatment. This allows researchers to isolate the effects of the electrical crowder on fish response and survival. When the treatment is applied, the flume will be set to velocities of 0.46 and 0.76 m/s (1.5 and 2.5 ft/s) and the response of striped bass and juvenile salmon to a rolling electrical crowder will be documented (upstream/downstream avoidance, twitch, taxis, tetanus). Striped bass will be tested one at a time. Salmon will be tested in groups of five since individual salmon are difficult to track in the model. Each fish will be measured and survival after 72 h will be recorded. The number of replicates required for the experiments will be statistically determined by the degree of variance.

If the electrical crowder is successful at moving fish downstream, the model will be modified to include a screen or perforated plate at a 25° angle and a 15.2-cm-wide (6-in-wide) bypass to the tailbox. The TFCF primary louvers are installed at a 15° angle, but the model cannot accommodate an angle greater than 25°. A rolling field will be applied to determine if striped bass chose to move through the bypass in order to avoid the electrical field without impingement on the angled screen.

In FY12, the laboratory experiments will be completed, a peer reviewed Tracy Series report will be written, and results will be shared at a Tracy Technical Advisory Team (TTAT) meeting.

Coordination and Collaboration

An aquatic scientist and hydraulic engineer from Reclamation's Technical Service Center will conduct all laboratory experiments. Researchers will coordinate with Brent Bridges at the TFCF if additional test fish are needed to complete experiments.

Endangered Species Concerns

None for laboratory flume experiments.

Dissemination of Results (Deliverables and Outcomes)

Investigators will produce a volume in the peer reviewed Tracy Technical Report Series as the expected deliverable from FY10 and FY11 activities. The report will include results of the stationary laboratory tests, results of the rolling electrical field flume tests, and an analysis of potential installation locations for electricity. Researchers also anticipate presenting findings at a TTAT meeting.

Literature Cited

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